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TERRESTRIAL MAGNETISM AND ELECTRICITY
OF
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The Editors

S_q-field in the Polar Region on Absolutely Quiet Days

By T. NAGATA and H. MAENO

Geophysical Institute, Tokyo University

(Received Nov. 15, 1955)

Abstract

It is proved by analyzing geomagnetic data on the quietest days during the Second Polar Year that the S-field over the whole surface of the earth on absolutely quiet days which are defined as the days when ΣK_n can be well represented by the extension of the S-field which has been defined by Chapman for the internal region of the earth. The S-field on the absolutely quiet days defined here will be called the S_q field.

1. Introduction

S_q-Field in the Polar Region on Absolutely Quiet Days

By T. NAGATA and H. MIZUNO

Geophysical Institute, Tokyo University

(Read Nov. 4, 1954; Received Aug. 18, 1955)

Abstract

It is proved by analyzing geomagnetic data on the quietest days during the Second Polar Year that the *S*-field over the whole surface of the earth on the absolutely quiet days which are defined as the days when $\Sigma K_p = 0$ can be well represented by the extension of the S_q-field which has been defined by Chapman for the interzonal region of the earth. The *S*-field on the absolutely quiet days defined here will be called the S_q^0-field.

1. Introduction

The S_q-field, that represents the daily variation in the geomagnetic field on magnetically quiet days, was defined by S. Chapman [1] as the field of the geomagnetic daily variations which covers the temperate and low latitude regions extending from 60°N to 60°S in latitude on the international magnetically quiet days. In the original presentation by Chapman, the S_q-field seems to represent the daily variation field only in the above-mentioned inter-zonal region, *i.e.* the region between the northern and the southern auroral zones, and does not necessarily cover the polar regions.

However, since J. Bartels [2] illustrated visually the S_q-field by the world-wide distribution of its equivalent overhead current-system which covered the whole surface of the earth, the assumption that an ideal case of the S_q-field might represent the daily variation on magnetically quiet days over the whole earth seems to have been implicitly adopted in some discussions on geomagnetic daily variations. For instance, the disturbance-daily variation field, *SD*, was defined by Chapman [3] that *SD* is equal to the daily variation field on the international magnetically disturbed days, S_d, minus S_q.

On the other hand, the daily variation field, *S*, in the polar region on the international quiet days, such as illustrated in Fig. 1, does resemble the *SD*-field in the same region, which is shown in Fig. 2. This fact seems to lead some people into a confusion about the conception of the S_q-field and that of the *SD*-field as well as their fundamental discrepancy. For example, M. Hasegawa [4] has proposed, on the base of his studies on the Second Polar Year data, the opinion that the *S*-field on quiet days has no fundamental difference from the S_d-field, though the former is much weaker than the latter. This seems quite true, es-

pecially in the polar regions, so far as the *S*-field on the international quiet days and that on the international disturbed days are concerned. But it is also true that the international quiet days are by no means safe from a certain amount of geomagnetic disturbances, as will be clear according to their definition. Actually, the mean value of the daily-sum of the K_p-indices ($\sum K_p$) on the international quiet days during the Second Polar Year period amounted to 5.1.

The first problem dealt with here is whether we can imagine the absolutely magnetically quiet days when the geomagnetic field is perfectly safe from any degree of geomagnetic storms which may be represented by the *D* field of $SD+D_{st}$ or by that of D_P+D_W [5, 6]. The second is how the *S*-field in this ideal case of the absolutely quiet days, if it exists, is far from or near the S_q-field which is defined as an extension of the field defined over the temperate and low latitudes to the whole surface of the earth.

2. The *S*-field on the international quiet days and disturbed days in the Second Polar Year

The distribution of geomagnetic north component (ΔX_m) of the average S-field in the northern polar region on the international quiet days during the Second Polar Year is illustrated in Fig. 1, which is derived from the geomagnetic data compiled by E.H. Vestine *et al* [7]. The magnetic observatories referred here are Thule (88.°0), Godhavn (79.°8), Chesterfield Inlet (73.°5), Julianehaab (70.°8), Fort Rae (69.°0), Tromsö (67.°1), College Fairbanks (64.°5), Lerwick (62.°5) and Sitka (60.°0), where the numerals in the parentheses denote the geomagnetic latitudes of respective observatories.

For the sake of comparison, Fig. 2 illustrates the distribution of ΔX_m of the average *SD*-field in the same region during the same period. The *SD*-field is derived from geomagnetic data from Godhavn, Chesterfield Inlet, Julianehaab, Point Barrow (68.°6), Matotchkin Shar (64.°1), Dickson (63.°0) and Sitka with reference also to Fort Rae, Tromsö, College Fairbanks and Lerwick.

As will be seen in Fig. 1, the general tendency of the pattern of distribution of ΔX_m on the quiet days well resembles that on the disturbed days, though ΔX_m under the auroral-zone in the former, amounting to about 30γ, is much less than that in the latter which exceeds 120γ, and the polar distance of the auroral zone in the former seems to be definitely smaller than that in the latter. In other words, the pattern of the S_q-field in the polar region does not seem to be fundamentally different from that of the *SD*-field. Only a marked characteristic in the S_q-field may be the extention of the area of negative values of ΔX_m up to high latitudes in the daylight hemisphere.

It must be remarked here that the average value of daily sum of the K_p-indices on the quiet days was 5.1, while that on the disturbed days was 28.1 [8]. We may be able to say therefore that the geomagnetic condition was not sufficiently quiet, on average, even on the five quietest days per every month during the

cially in the polar regions, so far as the S-field on the international quiet days and that on the international disturbed days are concerned. But it is also true that the international quiet days are by no means safe from a certain amount of geomagnetic disturbances, as will be clear according to their definition. Actually, the mean value of the daily-sum of the K_p-indices (ΣK_p) on the international quiet days during the Second Polar Year period amounted to 5.1.

The first problem dealt with here is whether we can imagine the absolutely magnetically quiet days when the geomagnetic field is perfectly safe from any degree of geomagnetic storms which may be represented by the D field of SD+ D_q or by that of D_p+D_q [5, 6]. The second is how the S-field in this ideal case of the absolutely quiet days, if it exists, is far from or near the S_q-field which is defined as an extension of the field defined over the temperate and low latitudes to the whole surface of the earth.

2. The S-field on the international quiet days and disturbed days in the Second Polar Year

The distribution of geomagnetic north component (ΔX-) of the average S-field in the northern polar region on the international quiet days during the data completed by IGY Western [7]. The geomagnetic observatories concerned here are Tixie (68.5°, 128.9°), Godhavn (69.2°, 306.8°), Resolute (74.7°, 265.1°), Meanook (54.6°, 246.7°), Fort Rae (62.8°, 244.0°), Fresno (36.7°, 240.1°), College Fairbanks (64.9°, 212.2°), Sitka (57.1°, 224.7°), Victoria (48.5°, 236.6°), where the numerals in the parentheses denote the geomagnetic latitudes of respective observatories.

For the sake of comparison, Fig. 3 illustrates the distribution of the average SD-field in the same region during the same period. The SD-field is derived from geomagnetic data from Godthavn, Cheltenham, Inlet, Valentia, Point Barrow, Meanook, Meteorite Bay, Dickson, Sitka with reference to Fort Rae, Thomas, College Fairbanks and Lerwick.

As will be seen in Fig. 1, the general tendency of the pattern of distribution of ΔX on the quiet days will resemble that on the disturbed days though under the auroral zone in the former, amounting to about 30% is much less than in the latter which exceeds 120%, and the polar distance of the point zone in the former seems to be definitely smaller than in the latter. In other words, the pattern of the S-field in the polar region does not seem to be fundamentally different from that of the SD-field. Only a marked characteristic in the S-field may be the existence of the area of negative values of ΔX up to high latitudes in the daytime hemisphere.

It must be remarked here that the average value of daily sum of the K_p-indices on the quiet days was 5.1, while that on the disturbed days was 28.1 [8]. We may be able to say therefore that the geomagnetic condition was not sufficiently quiet, on average, even on the five quietest days per every month during



Second Polar Year when the sunspot activity was near minimum.

If, on the other hand, we assume that the ideal pattern of S_q-field in the polar region can be obtained by extrapolating the S_q-field defined only for the temperate and low latitude (inter-zonal) region, being denoted by S_q^0, its pattern for ΔX_m is given as illustrated in Fig. 6. This pattern in the polar region is expressed by

$$\Delta X_m = \sum_n \sum_m (g_n^m \cos mt + h_n^m \sin mt) \frac{dP_n^m}{d\theta}, \qquad (1)$$

where t denotes the local time and the other symbols are due to the customary notations [9]. The coefficients g_n^m and h_n^m in (1) are determined from the analysis of the S_q-field only in the inter-zonal region. The actual pattern shown in Fig. 6 was obtained by assuming that the S_q-field is approximately expressed by

$$\Delta X_m = \sum_{m=1}^{3} (g_{m+1}^m \cos mt + h_{m+1}^m \sin mt) \frac{dP_n^m}{d\theta}, \qquad (2)$$

where g_n^m and h_n^m take the values given in the following table, which were obtained by M. Hasegawa and M. Ota [10] by analyzing the Second Polar Year data.

m	g_{m+1}^m	h_{m+1}^m
1	+10.10γ	−2.47γ
2	− 4.96	+1.61
3	+ 1.25	−0.95

In comparison of Fig. 1 with Fig. 6, we may notice that the area of negative ΔX_m in the daylight side in Fig. 1 seems to correspond, to a certain extent, to the similar characteristic of of the S_q-field, but that the circumpolar zone, having positive ΔX_m in the afternoon, in Fig. 1 has no correspondence in Fig. 6, being rather the most remarkable characteristic of the *SD*-field, as already mentioned before.

3. The *S*-field in the polar region on very quiet days in the Second Polar Year

Throughout the whole period of the Second Polar Year, there were several days when the geomagnetic condition was especially quiet. The dates of the quietest 6 days in this period are in the table. In this table, the geomagnetic activity throughout each day is represented by the value of $\sum K_p$.

Date	$\sum K_p$
Feb. 17, 1933	1_-
Jan. 10, 〃	2_0
Jan. 11, 〃	2_+
Jan. 15, 〃	〃
Feb. 11, 〃	〃
May. 26, 〃	〃

The patterns of ΔX_m component of the S_q-field in the polar region on these especially quiet days were derived from geomagnetic data from Thule (88.°0), Godhavn (79.°8), Scoresby Sund (75.°8), Sveagruvan (73.°9), Julianehaab (70.°8), Tromsö (67.°1), Petsamo (54.°9), Sodankylä (63.°8), Kandalaktcha (62.°5) and Lovö (58.°1). The pattern of $\Delta X_m(\varphi_m, t)$ averaged for the four days when $\sum K_p = 2_+$ is illustrated in Fig. 3, and the patterns on Jan. 10,

1933 when $\sum K_p = 2_0$ and on Feb. 17, 1933 when $\sum K_p = 1_-$ are shown respectively in Figs. 4 and 5.

Comparing these patterns with those in Fig. 6 and Fig. 2, we may say that the pattern of the *S*-field in the polar region changes from the *SD*-like configuration to the S_q-field in proportion to that $\sum K_p$ decreases and approaches zero.



Fig. 1. Distribution of geomagnetic north component (ΔX_m) of average daily variation field in the north polar region ($\theta = 0° \sim 30°$) on international quiet days in the II Polar Year. Unit = γ



Fig. 2. Distribution of geomagnetic north component (ΔX_m) of *SD*-field in the north polar region ($\theta = 0° \sim 30°$) during the II Polar Year.

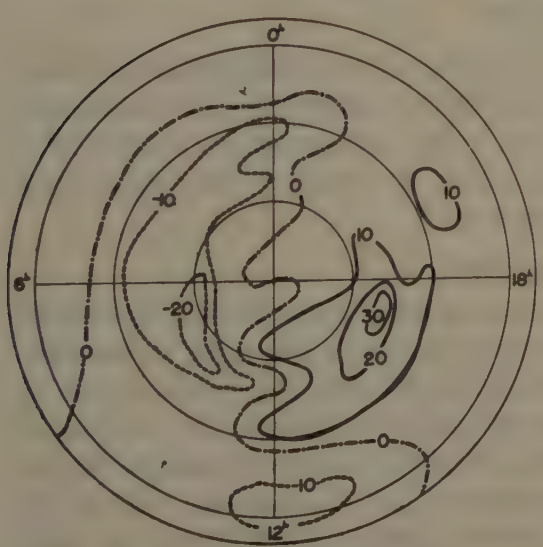


Fig. 3. Distribution of geomagnetic north component (ΔX_m) of average daily variation field, *S*, in the polar region ($\theta = 0° \sim 30°$) on the days when $\Sigma K_p = 2_+$ during the II Polar Year.

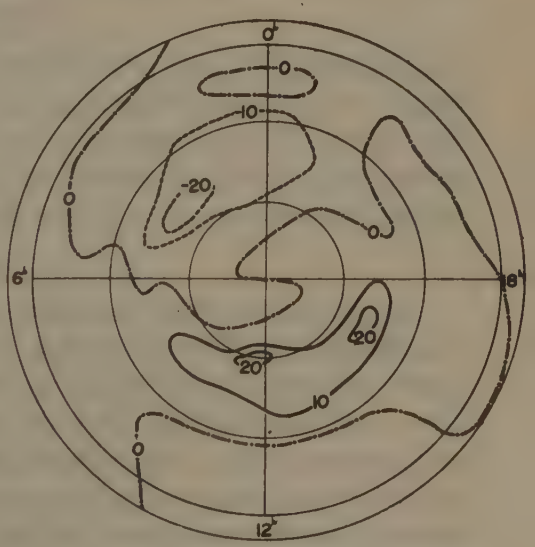


Fig. 4. Distribution of geomagnetic north component (ΔX_m) of daily variation field *S*, in the polar region ($\theta = 0° \sim 30°$) on Jan. 10, 1933 when $\Sigma K_p = 2_0$.





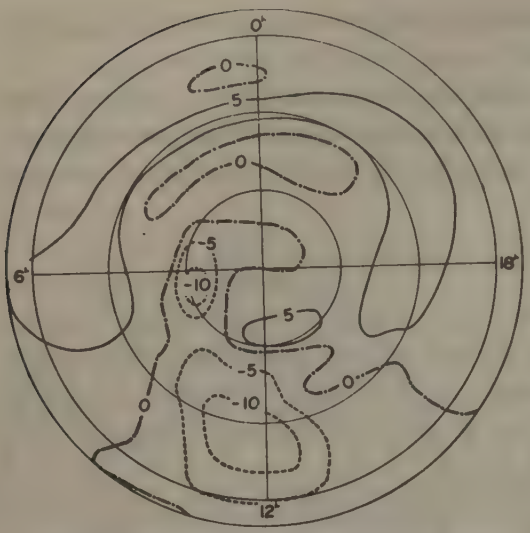


Fig. 5. Distribution of geomagnetic north component (ΔX_m) of daily variation, S, in the polar region ($\theta = 0^\circ \sim 30^\circ$) on Feb. 17, 1933 when $\Sigma K_p = 1-$.

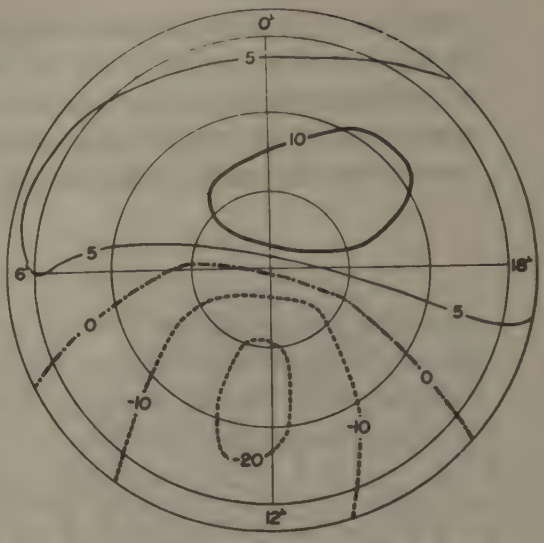


Fig. 6. Distribution of geomagnetic north component (ΔX_m) of S_q-field in the north polar region ($\theta = 0^\circ \sim 30^\circ$), as extrapolated from its distribution in the interzonal region.

Actually, the S-field pattern on the day of $\sum K_p = 1-$ (Fig. 5) seems to be almost similar to the S_q-field pattern given in Fig. 6, though it seems likely that the former is still under slight influence of the SD-like disturbance.

Summarizing these results, we may be able to state that the S-field in the polar region approach the S_q-field when the geomagnetic condition tends to the ideal case of absolute quietness; or more briefly speaking,

$$\lim_{\Sigma K_p \to 0} S = S_q^0. \qquad (3)$$

It seems likely from this view point that the S-field on the international quiet days, shown in Fig. 1, does not represent the real picture of distribution of geomagnetic daily variation on the ideal quiet days but rather corresponds to a pattern of a little disturbed S-field represented by $\sum K_p = 5.1$ in its degree of disturbance, being probably expressed by ($S_q^0 + SD$-like disturbance).

4. Conclusion

It may be concluded therefore that we can assume an ideal case of absolutely geomagnetically quiet day, being perfectly safe from any polar geomagnetic disturbance, and that the S-field on the absolutely quiet day, denoted here by S_q^0, is represented by the Chapman-Bartels' S_q-field throughout the whole parts of the earth's surface. This would mean, as will be reasonable, that on the international quiet days the SD-field is negligibly small in comparison with the S_q^0-field in the inter-zonal region, but the former is fairly predominant in the polar region.

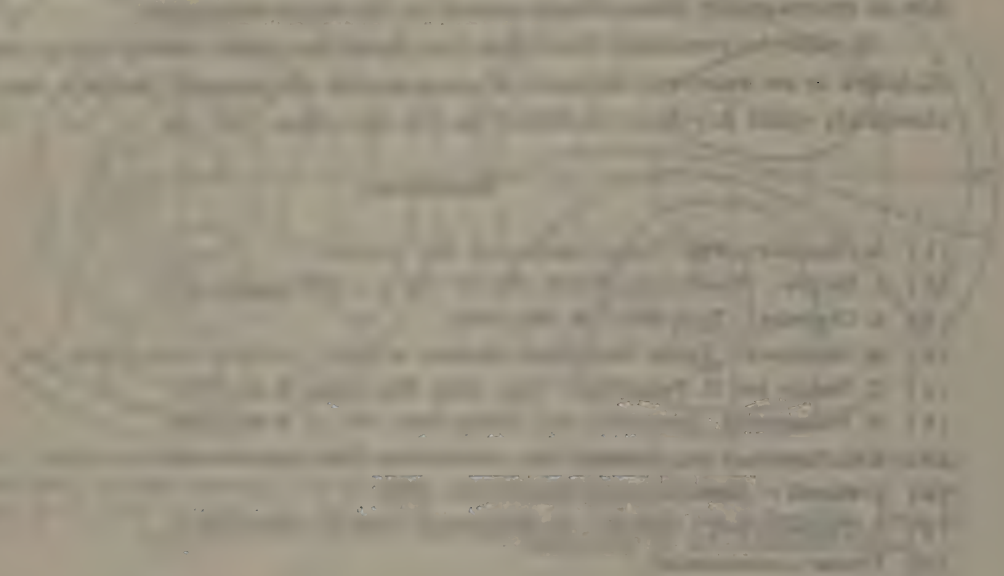
Thus we may clearly confirm here the conceptions of the S_q- and the SD-fields which have been frequently postulated by Chapman and Bartels; *i.e.* that

the S_q is the geomagnetic daily variation caused only by the solar radiation, being independent of any corpuscular disturbance, while the SD is the additive variation due to geomagnetic disturbances caused by the solar corpuscles.

It must be remarked here that this short note may merely verify that the K_p-index is an excellent measure of geomagnetic corpuscular activity, since the absolutely quiet day may be difined as the day when $\sum K_p = 0$.

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On the Disturbance Daily Variations and the Lunar Daily Variations in the $F2$ Region of the Ionosphere on the Magnetic Equator

By Hiroshi MAEDA

Geophysical Institute, Kyoto University

(Read May 8, 1955; Received Dec. 10, 1955)

Abstract

The paper examines the direct effects of the vertical electron drift, due to the electric fields accompanied by electric currents producing the observed geomagnetic S_D- and L-variations, upon the $F2$-region of the ionosphere on the magnetic equator. It is shown that the calculated results may explain the main features of the observed disturbance daily variations ($S_D(F2)$) and of the observed lunar daily variations ($L(F2)$) in the $F2$-region.

1. Introduction

Since D.F. Martyn [1] proposed a theory that the tidal variations in the ionospheric parameters, N_m, the maximum electron density, and h_m, the height at which this maximum occurs, can be interpreted as the effect of ionization drift, this drift theory has been further developed by Martyn [2] and many other workers [3] to explain the several variations in the $F2$-region of the ionosphere. In order to examine in detail the effects of ionization drift on the ionosphere, however, the electric fields in the ionosphere, which are accompanied by electric currents producing the observed geomagnetic variations, must be obtained. Moreover, to obtain the electric fields from the observed geomagnetic variations the daily variations of the electrical conductivity in the upper atmosphere must be estimated.

Along this line, the direct relation between the geomagnetic S_q-variations and the vertical electron drift in the $F2$-region on the magnetic equator was first examined by M. Hirono and H. Maeda [4], using the results of estimation of the daily variations of the electrical conductivity and the electric field by H. Maeda [5], and it was found that the main features of the anomaly in the $F2$-region on the magnetic equator could be well explained as the effect of the vertical electron drift, due to the electric field accompanied by S_q-electric currents, upon the $F2$-region on the equator. And further developments have been made by K. Maeda, M. Hirono, and H. Maeda [6].

In this paper, the effects of the vertical electron drift, due to the electric fields accompanied by S_D- and L-electric currents, upon the $F2$-region on the

magnetic equator are examined. The variations in the $F2$-region due to these effects may correspond to the observed $S_D(F2)$-and $L(F2)$-variations, so that the same notations, $S_D(F2)$ and $L(F2)$, as those used in the observed variations are also adopted for the results of calculation. The atmospheric and ionospheric models and the method of calculation used are the same as those in [4], hence these detailed descriptions are not repeated here.

2. The Electric Fields, $\Delta E(S_D)$ and $\Delta E(L)$

Under the assumption that the magnetic S_q-, S_D-, and L-variations are caused by the electric currents flowing mainly in the E-region of the ionosphere, we estimated [5] the eastward electric fields, $\Delta E(S_q)$, $\Delta E(S_D)$, and $\Delta E(L)$, in the E-region on the magnetic equator accompanied by these corresponding currents. The results for Case A of the ionospheric model (Fig. 1) used in [5] or in [4] were as follows [5]:

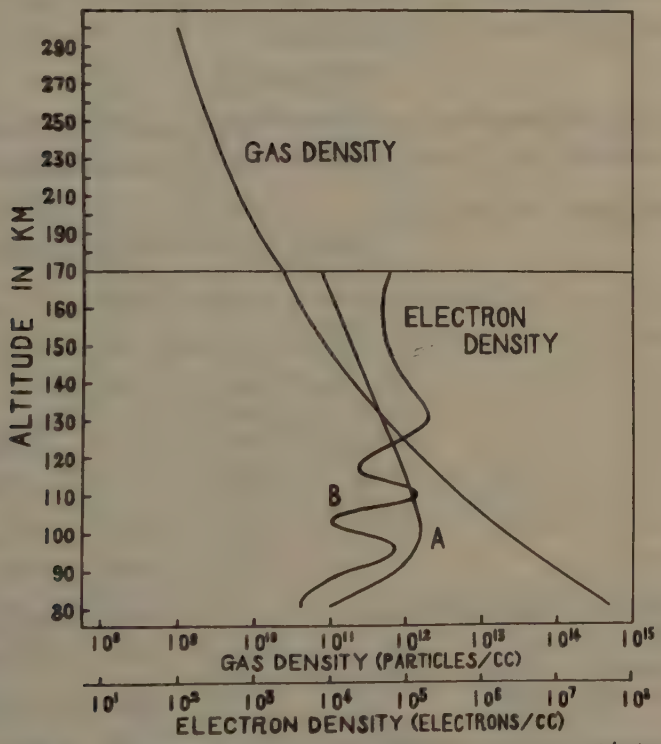


Fig. 1. Atmospheric model and distributions of electron density with altitude. Curve A denotes the Chapman layer, and curve B is inferred from rocket observations.

$$\left.\begin{aligned}\Delta E(S_q) &= 3.34\times10^2\sin(t+280^\circ)+0.36\times10^2\sin(2t+176^\circ)\ \text{e.m.u. for sp-min. period}\\ \Delta E(S_q) &= 4.19\times10^2\sin(t+265^\circ)+0.81\times10^2\sin(2t+171^\circ)\ \text{e.m.u. for sp-max. period}\end{aligned}\right\}(1)$$

$$\left.\begin{aligned}\Delta E(S_D) &= 2.14\times10^2\sin(t+30^\circ)+0.89\times10^2\sin(2t+18^\circ)\ \text{e.m.u. for sp-min. period}\\ \Delta E(S_D) &= 2.38\times10^2\sin(t+20^\circ)+1.18\times10^2\sin(2t+24^\circ)\ \text{e.m.u. for sp-max. period}\end{aligned}\right\}(2)$$





FIG. 2. Variation of $f(\omega) = V_1(\omega, M) = \omega_1/\omega$.

$$\Delta E(L)=0.74\times10^{2}\sin(2\tau-144^{\circ})\quad \text{e.m.u.} \tag{3}$$

where t and τ are the solar and lunar times respectively, and $\Delta E(L)$ represents the variation of ΔE with lunar time at noon. In Case B these amplitudes must be doubled.

According to the dynamo theory, the electromotive forces of the S_q-, S_D-, and L-currents on the magnetic equator are the electrostatic field. It is shown [7] from the theory of potential that the eastward components of these fields are almost constant between the E- and F-regions. Hence, the same electric fields as given by (1) to (3) may also exist in the F-region.

3. Method of Calculation of $S_D(F2)$ and $L(F2)$, and Its Results

(i) The $S_D(F2)$-variations

The effect of the vertical drift due to $\Delta E(S_D)$ upon the $F2$-region is calculated in the following manner: The vertical drift velocity W due to $\Delta E(S_q)+\Delta E(S_D)\equiv \Delta E(S_d)$ is first calculated by the expression

$$W=f(h)\Delta E/H,$$

where H is the magnitude of the earth's main magnetic field, and the distribution of $f(h)$ is shown in Fig. 2. By using this velocity the continuity equation

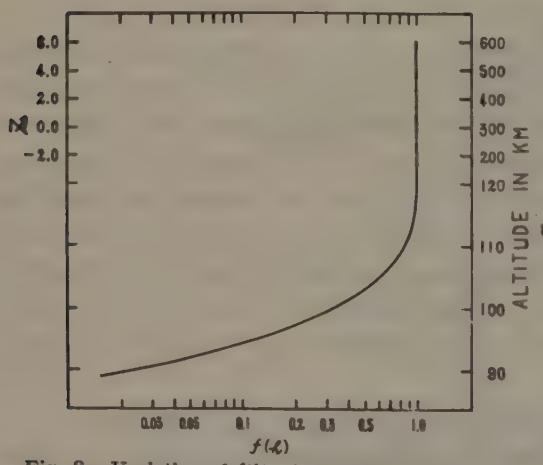


Fig. 2. Variation of $f(h)=W/(\Delta E/H)=p_i/(p_i+p_e)$ with altitude.

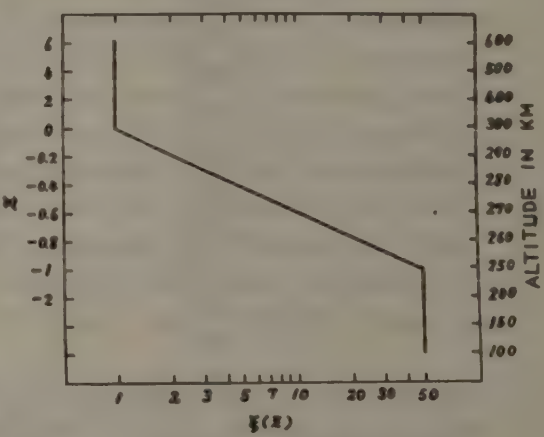


Fig. 3. Variation of $\xi(z)=\dfrac{\alpha(z)}{\alpha_0}$ with altitude

$$\frac{\partial N}{\partial t}=I-\alpha N^{2}-\frac{\partial}{\partial h}(N\cdot W)$$

is solved, where N stands for the electron density per c.c., I for the ion production per c.c. per sec., and α for the recombination coefficient as shown in Fig. 3 with $\alpha_0=8\times10^{-11}$ cc/sec. Thus, the daily variation curves (denoted by $S_d(F2)$) of the maximum electron density ν_m and the height h_m at which this maximum occurs are obtained. The results of calculation for several cases summarized in Table 1

are shown in Figs. 4A to 7A by dotted lines, in which Figs. 4 and 5 refer to the sunspot minimum period, and Figs. 6 and 7 to the sunspot maximum period.

On the other hand, the $S_q(F2)$-variations have previously been calculated in [4], and are shown again in Figs. 4A to 7A by full lines. Thus, the differences

Table 1.

Case	Figure and line illustrating	Electric field used in the calculation of the drift velocity	Ionospheric model used*	Height of maximum ion production	Continuity equation used*
1	4A (full line)	$\Delta E(S_q)$	*A*	300*km*	(14) with $\sigma_a=1$
	4A (dotted line)	$\Delta E(S_q)+\Delta E(S_D)$			
2	5A (full line)	$\Delta E(S_q)$	*B*	200*km*	(15) with $\sigma_b=1$
	5A (dotted line)	$\Delta E(S_q)+\Delta E(S_D)$			
3	6A (full line)	$\Delta E(S_q)$	*A*	300*km*	(14) with $\sigma_a=\frac{1}{2.5}$
	6A (dotted line)	$\Delta E(S_q)+\Delta E(S_D)$			
4	7A (full line)	$\Delta E(S_q)$	*B*	200*km*	(15) with $\sigma_b=\frac{1}{1.5}$
	7A (dotted line)	$\Delta E(S_q)+\Delta E(S_D)$			
5	8A (full line)	$\Delta E(S_q)$	*A*	300*km*	(14) with $\sigma_a=1$
	8A (dotted line)	$\Delta E(S_q)+\Delta E(L)$			
6	9A (full line)	$\Delta E(S_q)$	*B*	200*km*	(15) with $\sigma_b=1$
	9A (dotted line)	$\Delta E(S_q)+\Delta E(L)$			

* Notations and numbers of equation used here refer to those in a previous paper [4].

Table 2. *Harmonic coefficients of calculated S_D-variations in h_mF2 and ν_mF2.*

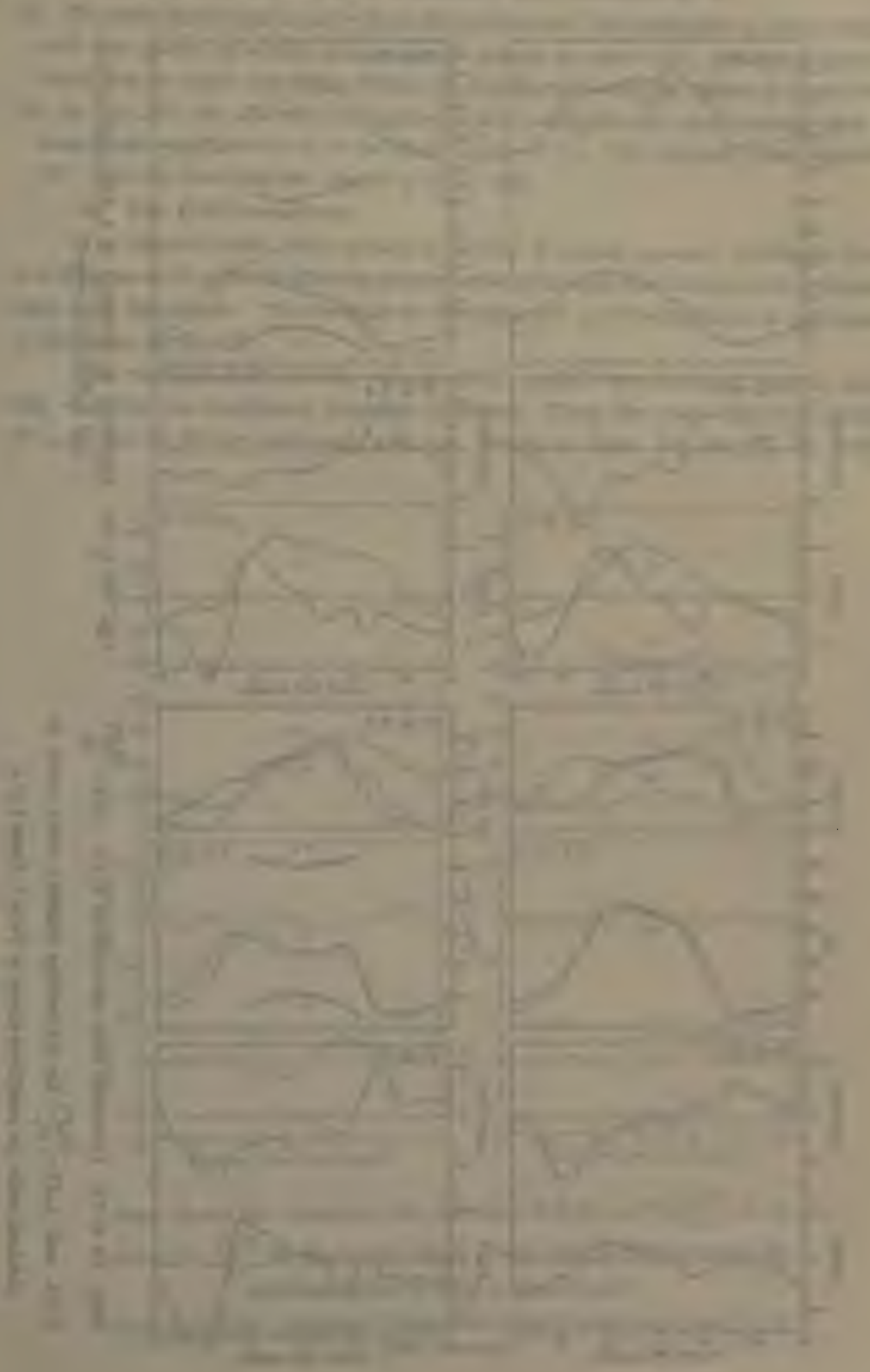
Case		P_1	t_1	P_2	t_2	P_3	t_3
1	$S_D(h_mF2)$	42.5*km*	5.4*h*	3.1*km*	2.3*h*	14.1*km*	6.8*h*
	$S_D(\nu_mF2)$	14.1%	13.8*h*	17.9%	4.4*h*	3.5%	0.8*h*
2	$S_D(h_mF2)$	23.5*km*	5.5*h*	9.3*km*	5.5*h*	9.1*km*	5.3*h*
	$S_D(\nu_mF2)$	16.4%	12.2*h*	12.3%	2.9*h*	11.2%	7.6*h*
3	$S_D(h_mF2)$	32.2*km*	6.3*h*	13.7*km*	1.6*h*	7.8*km*	7.6*h*
	$S_D(\nu_mF2)$	11.7%	13.7*h*	9.3%	4.2*h*	2.2%	7.4*h*
4	$S_D(h_mF2)$	35.0*km*	5.5*h*	11.6*km*	2.3*h*	9.2*km*	6.8*h*
	$S_D(\nu_mF2)$	15.6%	11.6*h*	15.6%	2.9*h*	9.3%	0.2*h*

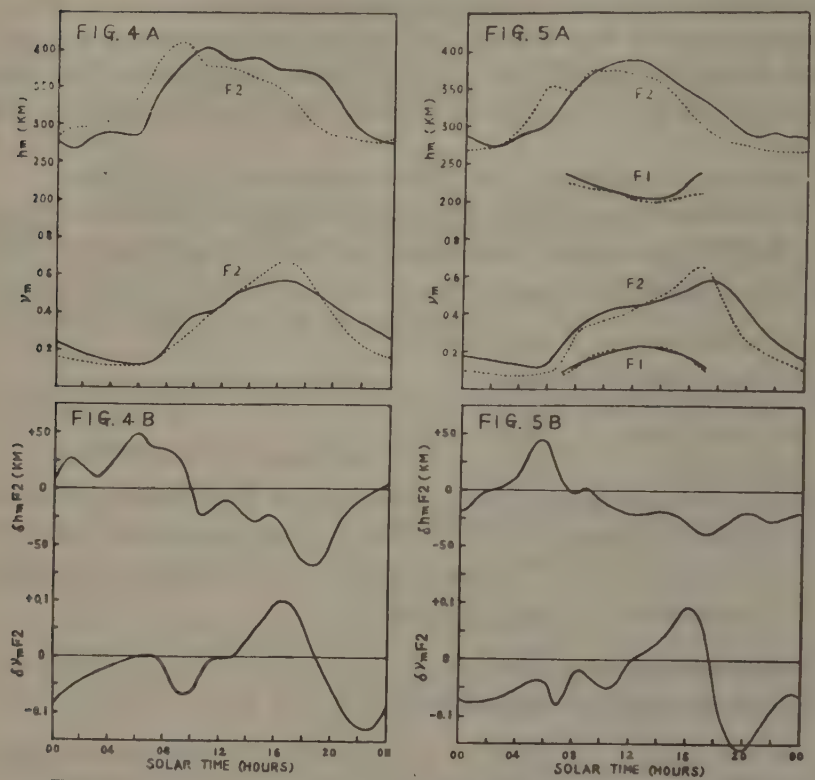
$$\delta h_mF2=S_d(h_mF2)-S_q(h_mF2)$$

and $$\delta\nu_mF2=S_d(\nu_mF2)-S_q(\nu_mF2)$$

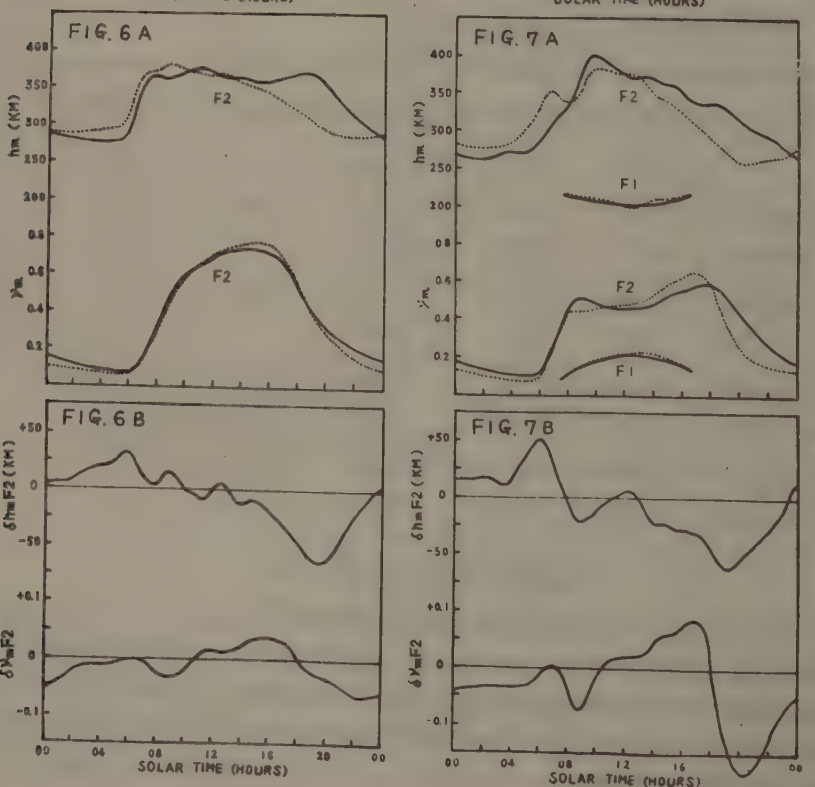
are obtained as shown in Figs. 4B to 7B, and these curves give the $S_D(F2)$-variations. The harmonic coefficients of $S_D(h_mF2)$ and $S_D(\nu_mF2)$ are shown in Table 2.

From this table the following general features for the calculated $S_D(F2)$-variations will be found:





Figs. 4B to 7B. Calculated S_{μ}-variations in h_mF2 [*upper curves*] and ν_mF2 [*lower curves*].



Figs. 4A to 7A. Calculated daily variations of h_mF2, $\nu_mF2 = \frac{N_mF2}{N_0}$, h_mF1, and $\nu_mF1 = \frac{N_mF1}{N_0}$ for the moving regions; every curve is obtained under the conditions shown in Table 1, Cases 1 to 4.

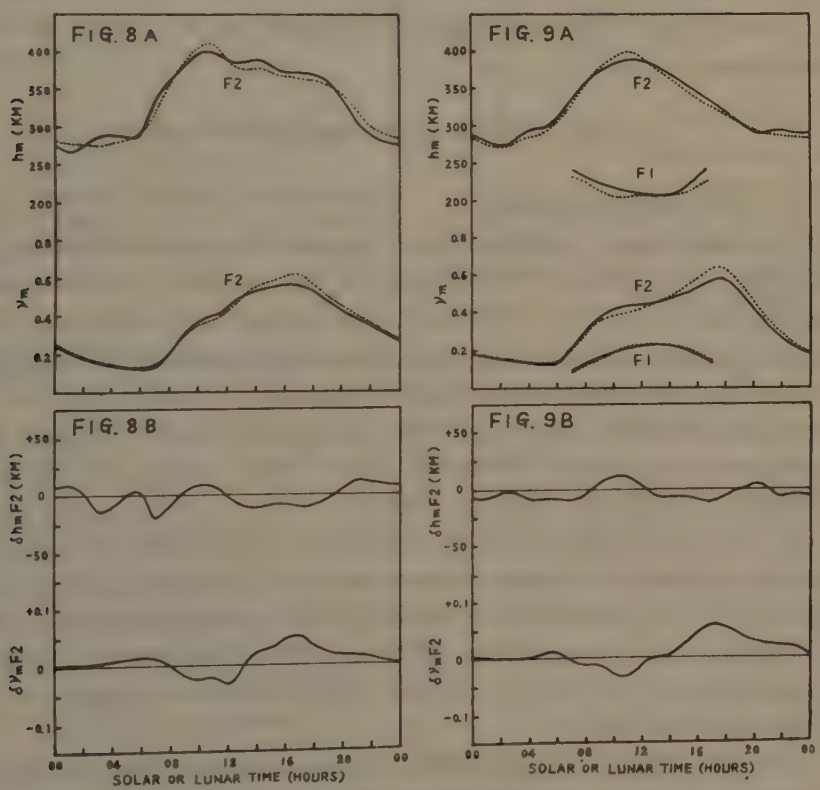
(1) The main harmonic term in $S_L(h_mF2)$ is diurnal. Its amplitude is about 30km, and the phase at which the maximum occurs is about 5.5^h. The semi-diurnal amplitude is about one third (10km) of the diurnal, and the phase is about 3^h.

(2) In $S_D(\nu_mF2)$ the diurnal and semi-diurnal amplitudes are about comparable in magnitude, and about 15% of the daily mean of ν_m. The diurnal phase is about 13^h, and the semi-diurnal phase is about 3.5^h.

(ii) The $L(F2)$-variations

The electric field $\Delta E(L)$ shown in section 2 refers to noon. Although there is a difference of about 50 minutes between the solar and lunar days, we here ignore this time difference. The method of obtaining the $L(F2)$-variations is analogous to the case of $S_D(F2)$.

The vertical drift velocity due to $\Delta E(S_q)+\Delta E(L)$ is calculated, and by using this velocity the continuity equation is solved. Thus, the daily variation curves of ν_mF2 and h_mF2 are obtained, and are shown in Figs. 8A and 9A by dotted



Figs. 8A and 9A Calculated daily variations of h_mF2, $\nu_mF2=\dfrac{N_mF2}{N_0}$, h_mF1, and $\nu_mF1=\dfrac{N_mF1}{N_0}$ for the moving regions; every curve is obtained under the conditions shown in Table 1, Cases 5 and 6.

Figs. 8B and 9B. Calculated L-variations in h_mF2 [*upper curves*] and ν_mF2 [*lower curves*].



lines. By subtracting the curves for S_q (shown in the same figure by full lines) from those for S_q+L, $\delta h_m F2$ and $\delta \nu_m F2$ are obtained (Figs. 8B and 9B). These curves give the $L(F2)$-variations at noon. The harmonic coefficients of $L(h_m F2)$ and $L(\nu_m F2)$ are shown in Table 3, and from this table the following general

Table 3. Harmonic coefficients of calculated L-variations in $h_m F2$ and $\nu_m F2$.

Case		P_1	t_1	P_2	t_2	P_3	t_3
5	$L(h_m F2)$	3.9km	0.1h	7.1km	10.0h	0.6km	5.0h
	$L(\nu_m F2)$	4.8%	19.0h	7.6%	5.0h	4.5%	7.3h
6	$L(h_m F2)$	1.7km	11.7h	5.6km	10.2h	4.3km	2.9h
	$L(\nu_m F2)$	7.4%	19.2h	6.1%	5.5h	1.6%	7.2h

features for the calculated $L(F2)$-variations will be found:

(1) The main term of $L(F2)$ is semi-diurnal.

(2) The semi-diurnal amplitude of $L(h_m F2)$ is about 6km, and the phase is about 10^h lunar time. The semi-diurnal amplitude of $L(\nu_m F2)$ is about 7%, and the phase is about 5^h.

4. The Observed $S_D(F2)$-and $L(F2)$-Variations

(i) The $S_D(F2)$-variations

The separation of $F2$-disturbance into $D_{st}(F2)$ and $S_D(F2)$ was first made by D.F. Martyn [2] and by K. Shinno [8]. The average S_D-variation of an ionospheric parameter ($foF2$ or $h'F2$) has been computed by Martyn [2], following the methods developed by J.A.F. Moos [9] and S. Chapman [10] for magnetic data, by subtracting for each month, its average daily variation for the five international magnetically quiet days from its average daily variation on the five international magnetically disturbed days. The results of his analysis for the Huancayo's data are shown in Fig. 10.

On the other hand, the daily variations of the values of many ionospheric parameters obtained at Ibadan, Nigeria (lat. 7.4°N; long. 3.9°E, magnetic lat. about 2.5°S), close to the magnetic equator, have been investigated by N.J. Skinner and R.W. Wright [11] on magnetically quiet days and on magnetically disturbed days. The $S_D(h'F2$, $h_m F2$, and $foF2)$-variations obtained from the results of their analysis are shown in Fig. 11.

The harmonic coefficients of the $S_D(F2)$-variations from these two stations are shown in Table 4. Although a good agreement can not always be found between the results from these two stations, the following general features may be drawn:

(1) The main term of $S_D(h'F2$ or $h_m F2)$ is diurnal. Its amplitude is about 10-20 km, and the phase is about 1^h. The semi-diurnal amplitude is about 8km, and the phase is about 4^h.

(2) In $S_D(N_mF2)$ the diurnal amplitude is predominant at Huancayo, but at Ibadan the diurnal and semi-diurnal amplitudes are comparable in magnitude (about 10%). The diurnal phase differs about 9hr. at two stations, but the semi-diurnal phase is about 1h.

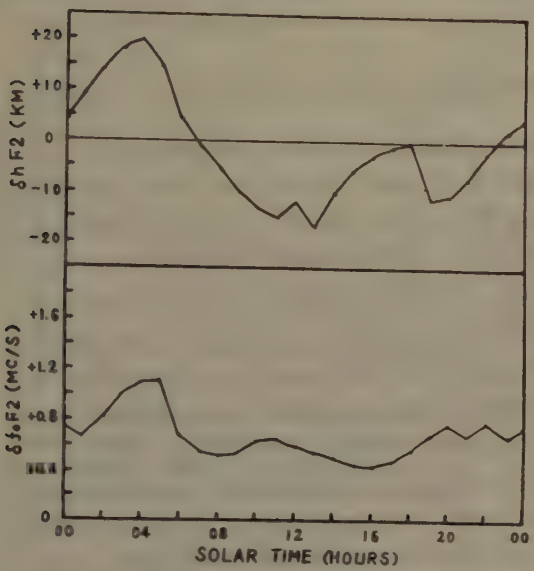


Fig. 10. Observed average S_D-variations in $h'F2$ [*upper figure*] and $foF2$ [*lower figure*] at Huancayo, 1942-48. (After D.F. Martyn)

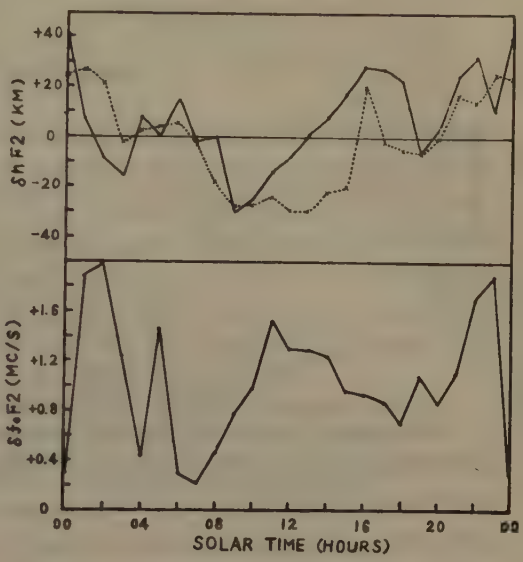


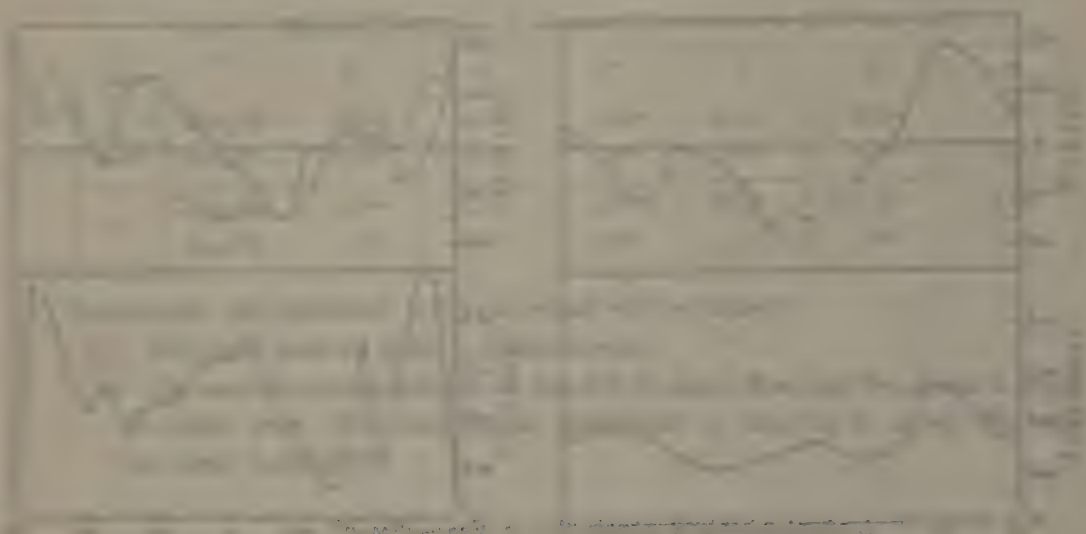
Fig. 11. Observed average S_D-variations in $h'F2$ [dotted line in *upper figure*], h_mF2 [full line in *upper figure*], and f_oF2 [*lower figure*] at Ibadan, 1952. (After N.J. Skinner and R.W. Wright)

Table 4. Harmonic coefficients of observed average S_D-variations in $h'F2$, h_mF2, and N_mF2 at Huancayo, 1942-48, and at Ibadan, 1952.

Station	Epoch		P_1	t_1	P_2	t_2	P_3	t_3
Huancayo	1942–48	$S_D(h'F2)$	11.8km	2.5h	8.5km	3.8h	1.2km	2.0h
		$S_D(N_mF2)$	4.3%	2.2h	1.3%	2.3h	3.2%	3.7h
Ibadan	1952	$S_D(h'F2)$	21.6km	23.4h	7.9km	3.6h	9.2km	7.8h
		$S_D(h_mF2)$	16.7km	21.2h	5.3km	4.5h	15.7km	7.0h
		$S_D(N_mF2)$	10.5%	16.9h	10.1%	0.0h	3.5%	4.1h

(ii) The $L(F2)$-variations

The lunar variation in the $F2$ region near the magnetic equator has been discussed by Martyn [1]. The results of his analysis for the Huancayo's data are shown in Fig. 12, and harmonic analysis of these variations gives the results shown in Table 5. It is noticed from his results that the main term is semi-diurnal and that its amplitudes and phases depend on solar time as shown in Fig 13. It is found from this figure that at noon the semi-diurnal amplitude and phase in h_mF2 are about 8km and 7h, and those in N_mF2 are about 9% and 3h, respectively.


SOLAR TIME (HOURS)
SOLAR TIME (HOURS)



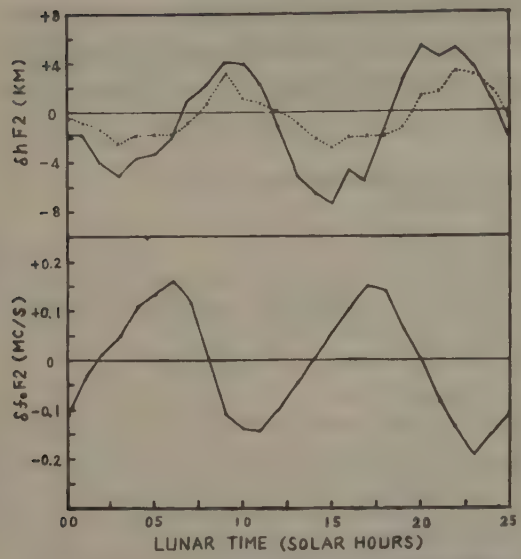


Fig. 12. Observed *L*-variations in *h'F2* [dotted line in *upper figure*], h_mF2 [full line in *upper figure*], and f_oF2 [*lower figure*] at Huancayo, 1942–44. (After D.F. Martyn)

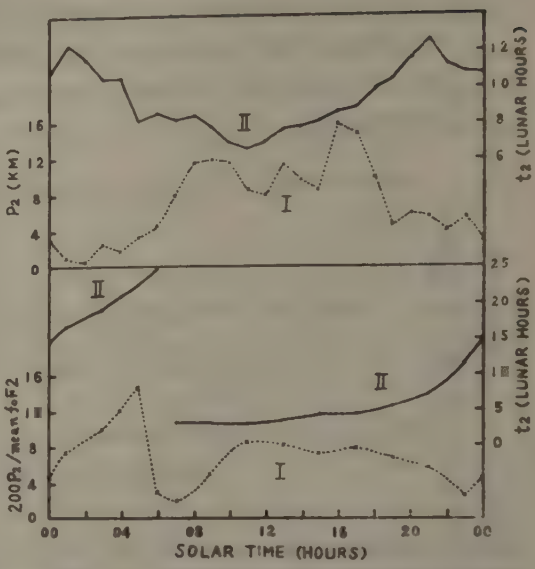


Fig. 13. Variation with solar time of the lunar harmonic coefficients P_2 (curve I) and t_2 (curve II) for h_mF2 [*upper figure*], and $200P_2$/mean *foF2* (curve I) and t_2 (curve II) for *foF2* [*lower figure*], Huancayo, 1942–44. (After D.F. Martyn)

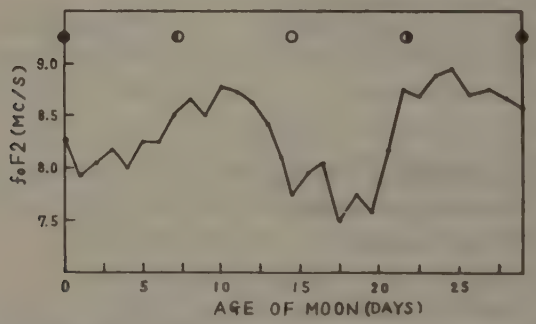


Fig. 14. Variation in *foF2*-at noon with age of moon for *E*-month (Mar., Apr., Sept., and Oct.), 1941–44, Huancayo. (After A.G. McNish and J.N. Gautier)

Tabel 5. *Harmonic coefficients of observed L-variations in h'F2, h_mF2, foF2, and N_mF2 at Huancayo,* 1942–44 *and* 1941-44.

Station	Epoch		P_1	t_1	P_2	t_2	P_3	t_3
Huancayo	1942–44 Average	$L(h'F2)$	0.51^{km}	22.2^h	2.32^{km}	9.2^h	0.06^{km}	6.3^h
		$L(h_mF2)$	1.46^{km}	22.6^h	5.20^{km}	8.4^h	0.94^{km}	5.6^h
		$L(foF2)$	$0.018^{mc/s}$	9.8^h	$0.113^{mc/s}$	4.3^h	$0.013^{mc/s}$	6.5^h
		$L(N_mF2)$	0.52%	9.8^h	3.25%	4.3^h	0.38%	6.5^h
	1942–44 Noon	$L(h_mF2)$			8^{km}	7^h		
		$L(N_mF2)$			9%	3^h		
	1941–44 Noon	$L(foF2)$	$0.183^{mc/s}$	11.6^h	$0.455^{mc/s}$	3.0^h	$0.058^{mc/s}$	0.7^h
		$L(N_mF2)$	4.4%	11.6^h	11.0%	3.0^h	1.4%	0.7^h

A.G. McNish and J.N. Gautier [12] have also obtained the lunar variation in $foF2$ at noon at Huancayo. Their results for E-month (Mar., Apr., Sept., and Oct.) during 1941-44 are shown in Fig. 14 and in Table 5. Also in this analysis the semi-diurnal term is predominant. Its amplitude is about 0.45 Mc/sec or 11%, and the phase is about 3^h.

5. Discussion of Results

The general agreement between calculated and observed $S_D(F2)$-variations will be seen from above results. In detail, however, the calculated amplitudes in $S_D(h_mF2)$ and $S_D(\nu_mF2)$ are slightly greater than the observed, and some phase difference between those is seen. The epoch of magnetic data used in the estimation of the electric fields is 1922-33, but that of ionospheric data is 1942-48 (at Huancayo) or 1952 (at Ibadan). Therefore, if the data used in the analysis of of magnetic and ionospheric S_D-variations were of the same epoch, then the calculated and observed results might show a better agreement.

On the other hand, the $L(F2)$-variations at noon calculated here show a fairly good agreement with the observed ones. In general, however, the amplitudes and phases of $L(F2)$ depend on solar time as pointed out by Martyn [1], so that more detailed studies of $L(F2)$ at several solar times are required. Moreover, in this case also the agreement in the epoch of magnetic and ionospheric data used is desirable.

In this paper we assumed that the electric fields in the F-region are the same as those in the E-region. However, the electric fields in the E- and F-regions may not be strictly the same, so that it is impossible, at present, to discuss in detail the phase difference between calculated and observed results.

6. Conclusion

From the studies made in [4] and in this paper, the following conclusion may be drawn: The main features of the observed $S_q(F2)$-, $S_D(F2)$-, and $L(F2)$-variations on the magnetic equator can be explained by the effects of the vertical electron drift, due to the electric fields accompanied by electric currents producing the observed magnetic S_q-, S_D-, and L-variations, upon the $F2$-region of the ionosphere. This conclusion may support the drift theory originated by Martyn on one hand, and the upper-atmospheric origin of the magnetic S_q-, S_D-, and L-variations on the other. Moreover, the requirement of further statistical and theoretical studies along those lines is emphasized.

7. Acknowledgments

The author wishes to express his sincere thanks to Professor M. Hasegawa for his kind direction throughout the study and to Professor K. Maeda, Professor T. Nagata, and Dr. M. Hirono for their valuable discussions and advice.

5. Discussion of Results

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LETTERS TO THE EDITOR

Report of Observations of Geomagnetic Variations at Aso and Naze (Amami-Oshima), during the Solar Eclipse of June 20th, 1955

(Received Jan. 17, 1956)

1. General Description

An attempt was made to examine precisely the variation of the terrestria magnetic field influenced outside the total solar eclipse, on June 20th, 1955. Fo this purpose, we constructed a temporary station at Naze, to add the Aso Magne tic Observatory.

The conditions of the eclipse were as follows:

Begining of eclipse;	12h30m	135°E.M.T.	12h20m	135°E.M.T.
Maximum of eclipse;	13 30	〃	13 30	〃
End of eclipse;	14 30	〃	14 40	〃
Degree of eclipse;	35%		50%	

2. Special Remark on Amami-Oshima Temporary Observatory

a) Variometer room.

Situation; The Naze Meteorological Station
Lat. 28°22′.1 N
Long. 129°30′.0 E

The magnetograph room was a concrete structure, and its dimension was 8 meter long, 5 meter wide and 4 meter high.

Daily variation of the room-temperature was about 1°C. Then Z value was corrected the temperature effect. Recording drum runs 20.5 mm. per hour. Fig. 1 shows the position of the room and the arrangement of the instruments.

b) Asbolute measurements were made at 3 stations. They were

1. Oshima High School
 Lat. 28°22′18″ N; Long. 129°30′07″ E
2. Oshima Business High School
 Lat. 28°22′07″ N; Long. 129°30′03″ E
3. Sedome Church
 Lat. 28°25′13″ N; Long. 129°35′41″ E

Fig. 2. shows each position of observations. The time of the observations was

The Oshima High School;	June 19th
The Oshima Business High School;	June 17th–18th, 20th and 25th
The Sedome Church;	June 23th



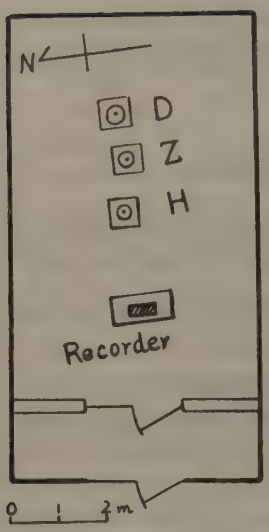


Fig. 1. Magnetograph room

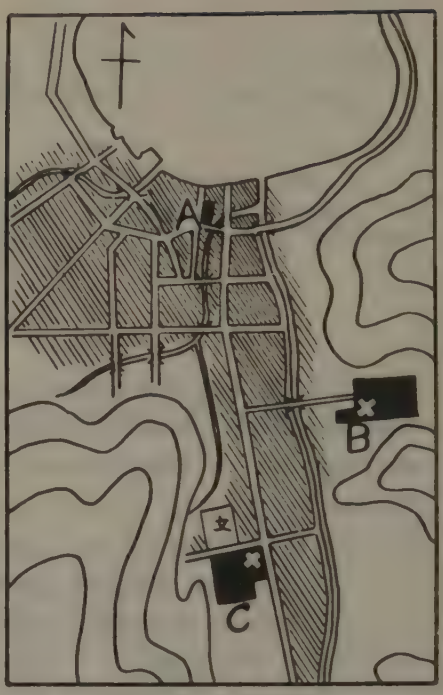


Fig. 2. The positions of observations.
A: The Naze Meorological Station.
B: The Oshima High School.
C: The Oshima Busiuess High School.

For determining the base value of each component, the result of the absolute measurements at the Oshima Business High School was referred to.

c) The sensibility of the instruments.

The sensibility of the instruments was measured by means of an attached Helmholts coil, and its values are as follows:

	Sensibility	Temperature Coefficient
Declination D	0′.43/mm	0
Horizontal intensity H	0.75-1.42γ/mm	0
Vertical intensity Z	5.17γ/mm	4°.5/C

Sensibility of the D and Z variometers was constant throughout the whole duration. But that of H was a function of scale value as given by the following expression which was deduced through the special experiment on June 26 by the same settlement:

$$H_n = H_o + \int_o^n \alpha(n)dn$$

$$\alpha(n) = 1.8 \times \{0.418 + 0.0038n + 0\text{-}0004(n_s - 50)\}\gamma/\text{mm}$$

where H_n; H-value when the scale is n,

H_o; base value,

n_s, n; reading of scale value in mm,

and n_s is adopted when n is larger than 50 mm.

3. Magnetograph Values on June 20th, 1955

Date	Time h	Time m	H ASO 31700γ+···	H NAZE 34225γ+···	D ASO W5 00′+···	D NAZE W3 49′.8+···	Z ASO 34500γ+···	Z NAZE 28700γ+···
20	00	00	90γ	93γ	6.6′	8.0′	75γ	58γ
		15	88	89	6.8	8.1	75	59
		30	85	85	6.7	8.0	75	59
		45	85	86	6.8	8.0	75	58
	01	00	86	88	6.7	8.0	75	58
		15	88	90	6.8	8.0	76	59
		30	87	89	6.8	8.1	75	60
		45	84	87	6.7	8.1	75	60
	02	00	84	86	6.6	7.9	74	59
		15	84	86	6.7	8.0	75	59
		30	84	85	6.6	8.0	75	59
		45	84	84	6.6	7.9	75	59
	03	00	84	84	6.6	7.8	76	59
		15	85	84	6.6	7.9	77	59
		30	84	84	6.5	7.8	77	59
		45	84	83	6.5	7.8	77	59
	04	00	83	83	6.4	7.7	77	58
		15	84	83	6.4	7.7	77	61
		30	83	81	6.4	7.7	77	60
		45	83	81	6.2	7.6	78	59
	05	00	83	81	6.0	7.5	78	57
		15	83	80	5.8	7.3	79	57
		30	84	81	5.5	7.0	81	56
		45	85	81	4.9	6.6	81	55
	06	00	85	81	4.6	6.3	81	55
		15	84	81	4.2	6.0	80	55
		30	84	80	3.9	5.7	79	55
		45	83	80	3.5	5.4	78	55
	07	00	85	82	2.6	4.6	78	50
		15	84	82	2.6	4.5	77	50
		30	84	83	2.7	4.4	75	48
		45	82	82	3.0	4.5	72	47
	08	00	81	82	3.2	4.5	71	45
		15	80	81	3.5	4.6	67	42
		30	81	80	4.0	4.9	66	41
		45	82	81	4.2	5.1	65	39
	09	00	82	82	4.5	5.6	63	41
		15	82	82	4.7	6.0	60	42
		30	83	84	4.7	6.1	60	41
		45	80	84	5.1	6.6	58	41
	10	00	80	87	5.5	7.0	58	41
		15	80	90	5.9	7.3	57	40
		30	84	95	6.4	7.8	56	39
		45	86	99	6.5	8.1	57	39



Time	H	D				
15	96	108	8.1	9.1	64	43
30	95	107	8.2	9.2	64	43
45	98	110	8.0	9.0	65	44
12 00	99	111	8.0	9.0	65	44
15	100	112	8.0	9.0	65	45
30	101	113	7.9	8.9	66	45
45	102	114	7.9	8.9	66	46
13 00	103	115	7.8	8.8	67	46
15	104	116	7.8	8.8	67	47
30	105	117	7.7	8.7	68	47
45	106	118	7.7	8.7	68	48
14 00	107	119	7.6	8.6	69	48
15	108	120	7.6	8.6	69	49
30	109	121	7.5	8.5	70	49
45	110	122	7.5	8.5	70	50
15 00	111	123	7.4	8.4	71	50
15	110	122	7.5	8.5	70	50
30	109	121	7.6	8.6	69	49
45	108	120	7.6	8.6	69	49
16 00	107	119	7.7	8.7	68	48
15	106	118	7.7	8.7	68	48
30	105	117	7.8	8.8	67	47
45	104	116	7.8	8.8	67	47
17 00	103	115	7.9	8.9	66	46
15	102	114	7.9	8.9	66	46
30	101	113	8.0	9.0	65	45
45	100	112	8.0	9.0	65	45
18 00	99	111	8.0	9.0	65	44
15	98	110	8.1	9.1	64	44
30	97	109	8.1	9.1	64	43
45	96	108	8.1	9.1	64	43
19 00	95	107	8.2	9.2	64	43
15	94	106	8.2	9.2	64	43
30	93	105	8.3	9.3	64	42
45	92	104	8.3	9.3	64	42
20 00	91	103	8.4	9.4	64	42
15	90	102	8.4	9.4	64	42
30	89	101	8.5	9.5	64	41
45	88	100	8.5	9.5	64	41
21 00	87	99	8.6	9.6	64	41
15	86	98	8.6	9.6	64	41
30	85	97	8.7	9.7	64	41
45	84	96	8.7	9.7	64	41
22 00	83	95	8.8	9.8	64	41
15	82	94	8.8	9.8	64	41
30	81	93	8.9	9.9	64	41
45	80	92	8.9	9.9	64	41
23 00	79	91	9.0	10.0	64	41
15	78	90	9.0	10.0	64	41
30	77	89	9.1	10.1	64	41
45	76	88	9.1	10.1	64	41
24 00	75	87	9.2	10.2	64	41

Date	Time		H		D		Z	
	h	m	ASO 31700γ + ⋯	NAZE 34225γ + ⋯	ASO W5° 00′ + ⋯	NAZE W3° 49′.8 + ⋯	ASO 34500γ + ⋯	NAZE 28700γ + ⋯
	11	00	87γ	101γ	7.2′	8.9′	55γ	39γ
		15	89	103	7.9	9.4	54	39
		30	94	106	8.1	9.4	54	41
		45	95	105	8.6	9.8	54	43
	12	00	98	106	8.6	9.9	55	45
		15	99	106	8.6	10.0	55	45
		30	98	106	8.7	10.2	57	47
		45	98	107	8.7	10.1	56	47
	13	00	96	108	8.6	10.0	55	47
		15	97	109	8.6	9.8	54	46
		30	97	111	8.6	9.6	54	45
		45	101	116	8.5	9.5	54	45
	14	00	102	118	8.3	9.5	54	47
		15	101	117	8.4	9.6	54	48
		30	103	117	8.5	9.5	55	49
		45	102	114	8.4	9.5	56	50
	15	00	100	111	8.1	9.4	58	50
		15	97	110	8.1	9.3	58	50
		30	98	108	8.1	9.3	59	50
		45	97	107	7.9	9.1	60	49
	16	00	95	104	7.7	8.9	62	48
		15	95	104	7.5	8.8	64	48
		30	95	102	7.4	8.7	65	50
		45	93	100	7.2	8.5	67	51
	17	00	93	99	6.8	8.3	69	47
		15	90	97	6.7	8.2	70	51
		30	90	96	6.4	8.3	72	50
		45	90	98	6.3	8.3	72	52
	18	00	92	98	6.0	7.6	74	54
		15	91	100	5.9	7.4	74	54
		30	91	99	5.8	7.3	74	55
		45	93	101	5.8	7.3	73	55
	19	00	94	102	5.9	7.4	72	57
		15	96	103	5.9	7.4	72	57
		30	99	108	6.0	7.3	74	56
		45	97	106	5.9	7.0	73	56
	20	00	97	105	6.1	7.5	73	56
		15	97	107	6.4	7.6	74	56
		30	98	106	6.4	7.7	75	56
		45	98	106	6.4	7.8	75	56
	21	00	96	104	6.8	8.0	75	57
		15	101	107	6.8	8.0	75	57
		30	103	111	6.8	8.0	75	58
		45	103	112	6.7	8.0	75	59

Date	Time		H		D		Z	
	h	m	ASO 31700γ+…	NAZE 34225γ+…	ASO W5°00′+…	NAZE W3°49′.8+…	ASO 34500γ+…	NAZE 28700γ+…
	22	00	105γ	114γ	6.7′	8.0′	74γ	60γ
		15	106	116	6.7	7.8	74	59
		30	106	115	6.7	7.8	74	59
		45	104	115	6.8	8.0	74	57
	23	00	106	116	6.8	8.0	74	59
		15	104	113	6.8	8.1	75	59
		30	103	113	6.9	8.1	74	59
		45	104	114	6.6	7.9	76	59

Masaziro OTA, Hiroshi MAEDA,
Hiromichi YASUHARA, and
Shoichiro HASHIZUME

Aso Magnetic Observatory, Kyoto University

22	100	109	114	6.7	8.2	74	89
18	104	110	116	6.7	7.8	74	89
16	106	112	117	6.6	7.9	74	89
15	104	110	115	6.5	8.0	74	89
22	104	109	114	6.6	8.1	74	89
15	104	110	115	6.5	8.1	75	90
20	104	110	115	6.4	8.1	74	89
16	104	110	114	6.6	7.9	75	89



Sequential E_S and Lunar Effects on the Equatorial E_S

(Received Jan. 17, 1956)

Sporadic-E(E_s) is a peculiar region of the ionosphere, and its origin is not yet known. Among the various types of E_s, one shows apparent vertical movement on the ionogram, and it has, in many cases, ordinary and extraordinary rays (see Fig. 1). This phenomenon has not been widely studied,* although it

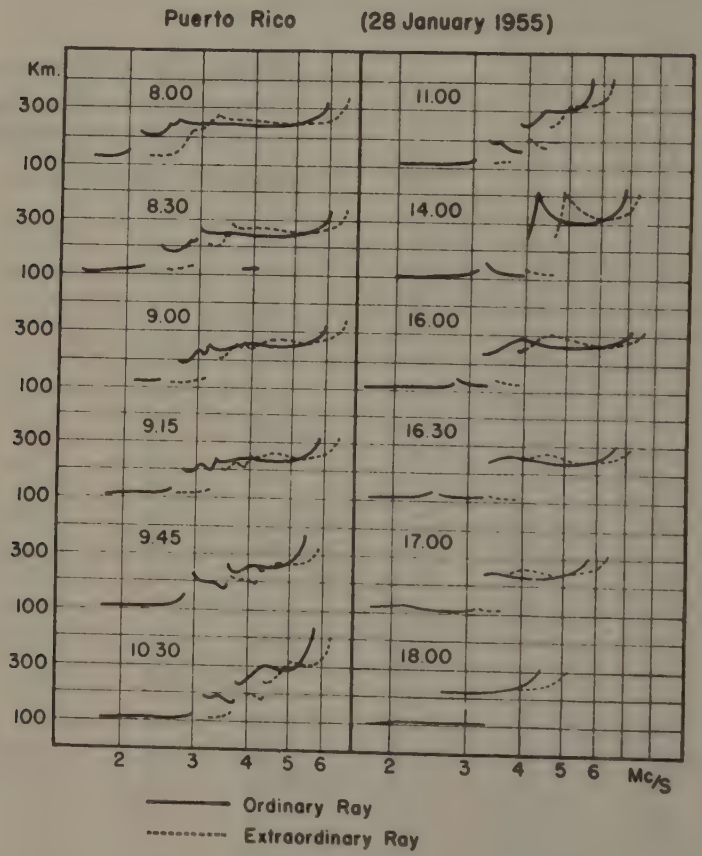


Fig. 1

* During the course of my preparation of this publication, A.K. Saha and S. Ray have published a short note on the E_2 layer observed at Haringhata, Calcutta (Journ. Atmos. Terr. Phys., *7*, 107, 1955). The E_2 mentioned there seems to be the Seq. E_s discussed here. The time at which their E_2 layer effect to occur at Haringhata is consistent with the results shown in Fig. 3.

N.J. Skinner, R.A. Brown and R.W. Wright have discussed "ridges" in the F_1 layer observed at Ibadan (Journ. Atmos. Terr. Phys., *5*, 92, 1954). These ridges may be the morning and evening types of sequential E_s, and also Seq. E_s at the equatorial region. On the other hand, E.L. Hagg and G.H. Hanson have discussed the motion of ionized clouds observed in Northern Canada (Canad. Journ. Phys.. *32*, 790, 1954). These are not the Seq. E_s, but the phenomenon which has been referred to as "type I" may be the morning and evening types of sequential E_s at higher latitudes.

has been noted as "sequential E_s" by some of the people who scale ionograms at the National Bureau of Standards in America. The author has investigated this phenomenon from records made at Huancayo, Talara, Guam, Okinawa, Panama Canal Zone, Maui, Puerto Rico, White Sands, Washington, Fort Monmouth, Adak, Anchorage, Fairbanks, Point Barrow, Narsarssuak and Godhavn, using ionograms obtained by the National Bureau of Standards.

Sequential E_s may be classified into three types. The first is the "morning type," which appears in the early morning and apparently comes down, then apparently goes up. The second is the "evening type," which appears in the evening and gradually descends—at the same time, the maximum frequency decreases. These two types may be due to the effect of sunrise and sunset at this level. At higher latitudes, both morning and evening types decrease in height and then increase in height again. These effects may be due to reflections from clouds moving horizontally. The sequential E_s that seems to move generally downward and persists more than three hours (except at Huancayo) is the third type (see Fig. 1). In the present report, this type of sequential E_s is called Seq. E_s, and its behavior on undisturbed days is treated statistically. This phenomenon occurs both on magnetically quiet and disturbed days throughout the year, although it does not occur at the higher latitudes in winter.

Seq. E_s first appears at about 200 km in winter and about 180 km in summer (see Fig. 2), and then comes down to the normal E level. When Seq. E_s reaches about 130 km, the ordinary ray often merges with the extraordinary ray and becomes similar to the

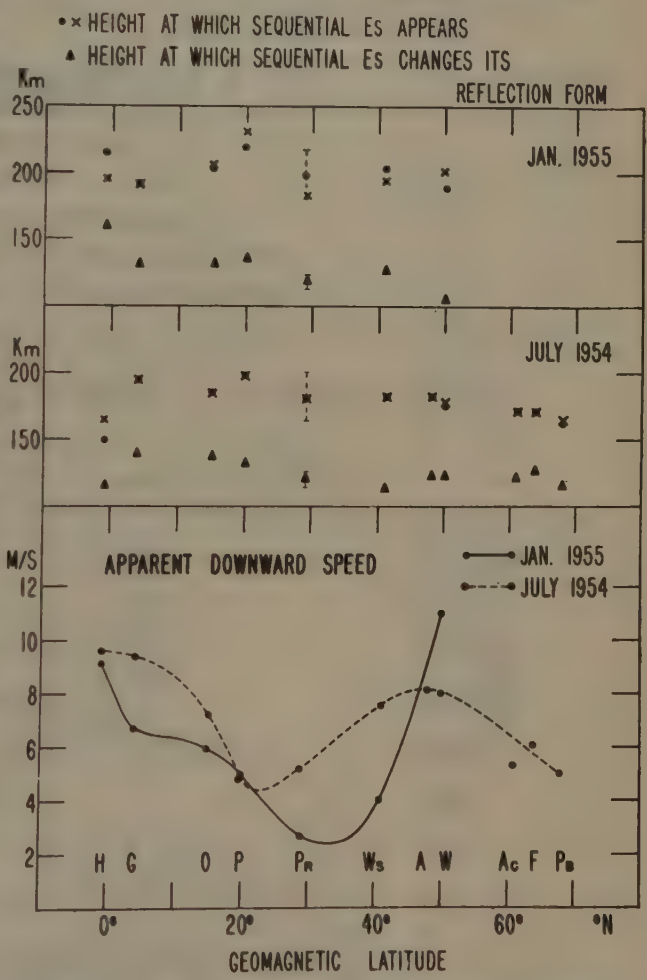
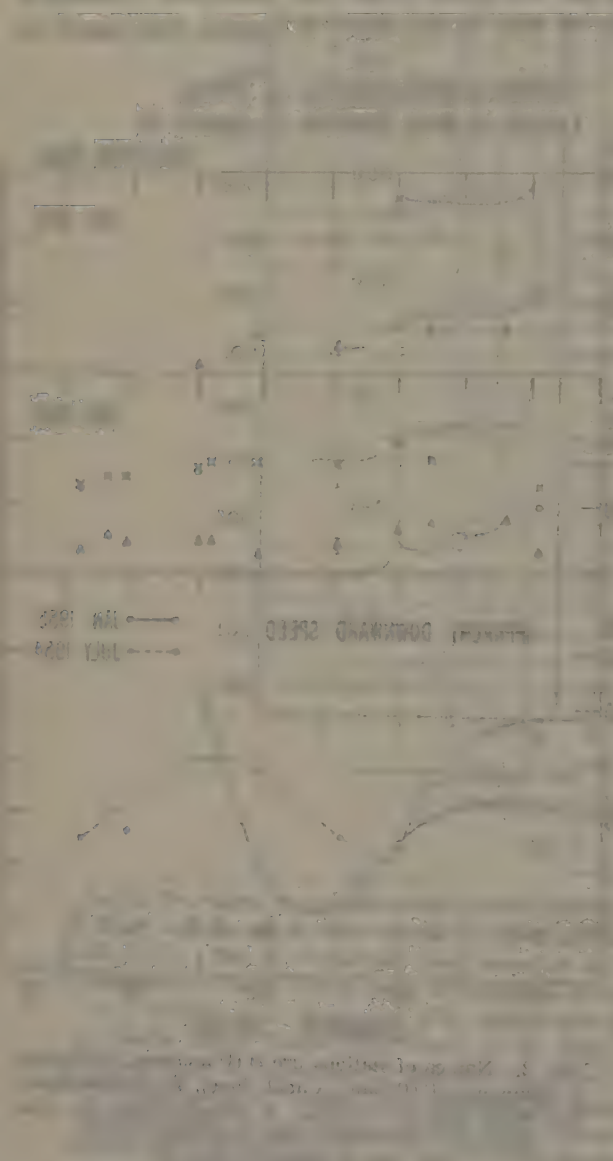
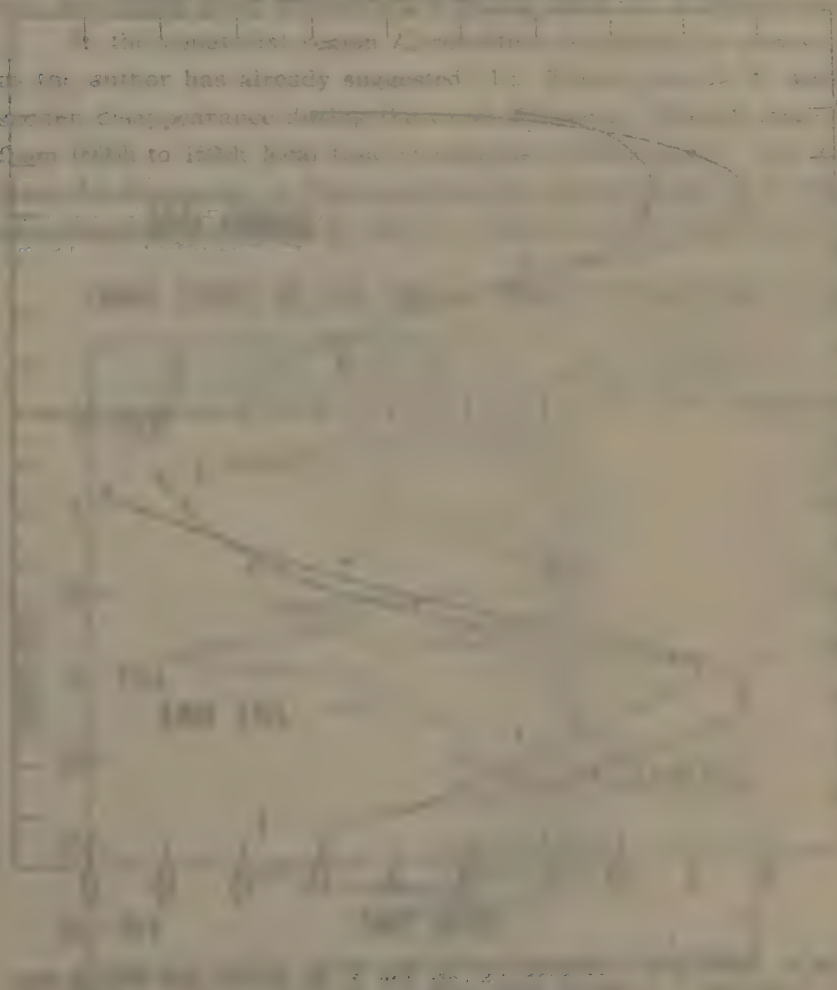


Fig. 2. Names of stations are H (Huancayo), G (Guam), O (Okinawa), P (Panama Canal Zone), P_R (Puerto Rico), W_S (White Sands), A (Adak), W (Washington), A_C (Anchorage), F (Fairbanks) and P_B (Point Barrow).
× for all types of Seq. E_s
● for the merger type of Seq. E_s





linear type of E_s (see Fig. 1). This type of Seq. E_s is named the "merger type." The Seq. E_s that does not merge often disappears at a level higher than about 130 km, or quickly disappears at 130 km or less. Average apparent downward speeds of the merger type of Seq. E_s between the two levels at which it appears and merges are shown in the lower part of Fig. 2. The average speed is higher in summer than that in winter, and the minimum speed occurs at lower latitudes in summer than in winter. It may be noticed that the geomagnetic latitude at which these minima occur corresponds to the latitude of the S_q current-focus in each season. The variation of maximum frequency of the ordinary ray seems to have a maximum at about noon (the value is about 4 Mc/s).

In winter the Seq. E_s occurs at stations from the equator to about 50° N geomagnetic latitude, and most frequently at 20°-30°N geomagnetic latitude. The

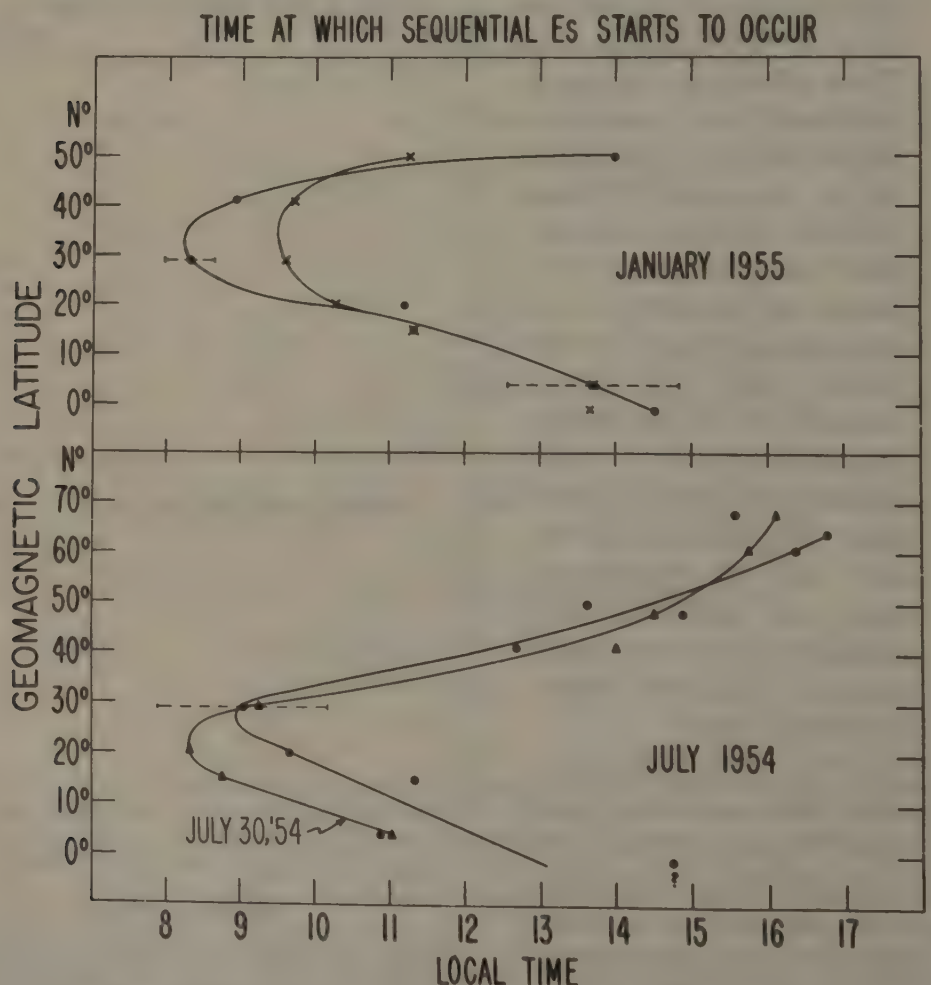


Fig. 3. Initial time of occurrence of the Seq. E_s for January 1955 and July 1954.
× for all types of Seq. E_s
• for the merger type of Seq. E_s.

occurrence frequency is about 90% there, and 40-50% at other latitudes. More than half of the cases are the merger type of Seq. E_s (about 30% of occurrence). In summer, the Seq. E_s occurs at stations from the equator to about 70° N geomagnetic latitude. The occurrence frequency is about 30%, and almost all of them are the merger type.

The time at which the Seq. E_s starts to occur seems to depend on the geomagnetic latitudes of the station (see Fig. 3). It occurs at the earliest time in the morning at about 30°-40° N geomagnetic latitude in summer and about 20°-30° N in winter. It is interesting that these latitudes also correspond to those of the S_q current-focus in summer and in winter respectively.

The phenomenon of Seq. E_s may be a downward motion of a real ionized cloud. If such is the case, a possible explanation of this phenomenon, which fits all results so far obtained, may be that excess charges at the focus of the S_q electric current go up along the magnetic lines of force, flow in the F_1 region, and then come down toward the E region along the magnetic lines of force.

In the equatorial region E_s reflection is abnormally intense in the daytime, as the author has already suggested [1]. This equatorial E_s occasionally shows sudden disappearance during the early afternoon, although large fE_s values occur from 0900h to 1500h local time in monthly median values. The author concludes from the ionograms at Huancayo from May 1954 through April 1955, that the disappearance of equatorial E_s seems to depend on the lunar phase (see Fig. 4). In

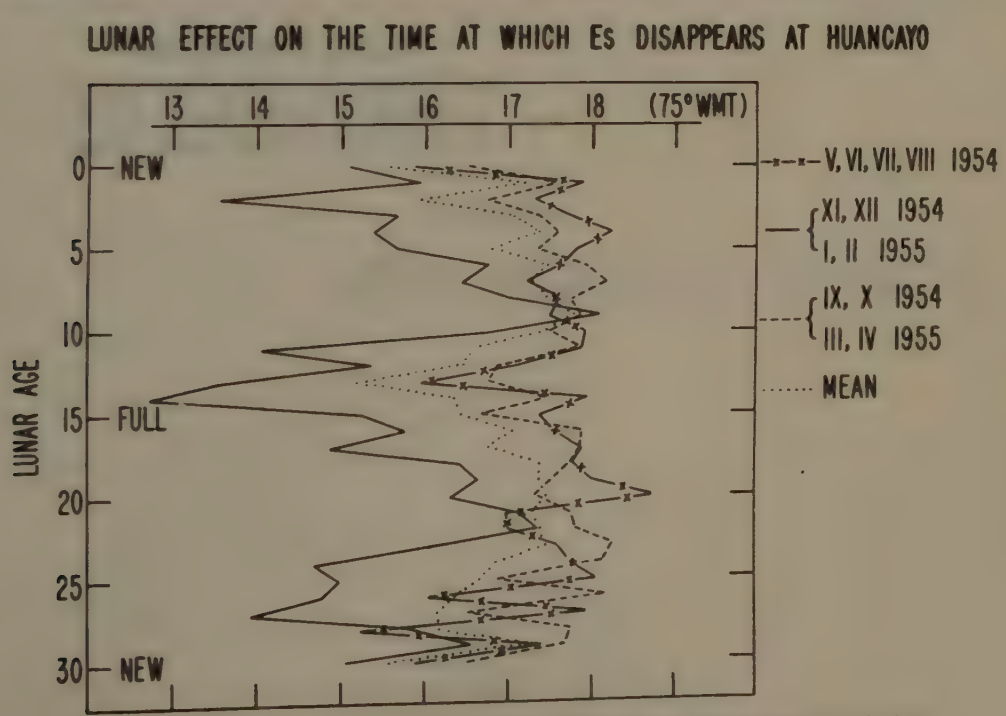
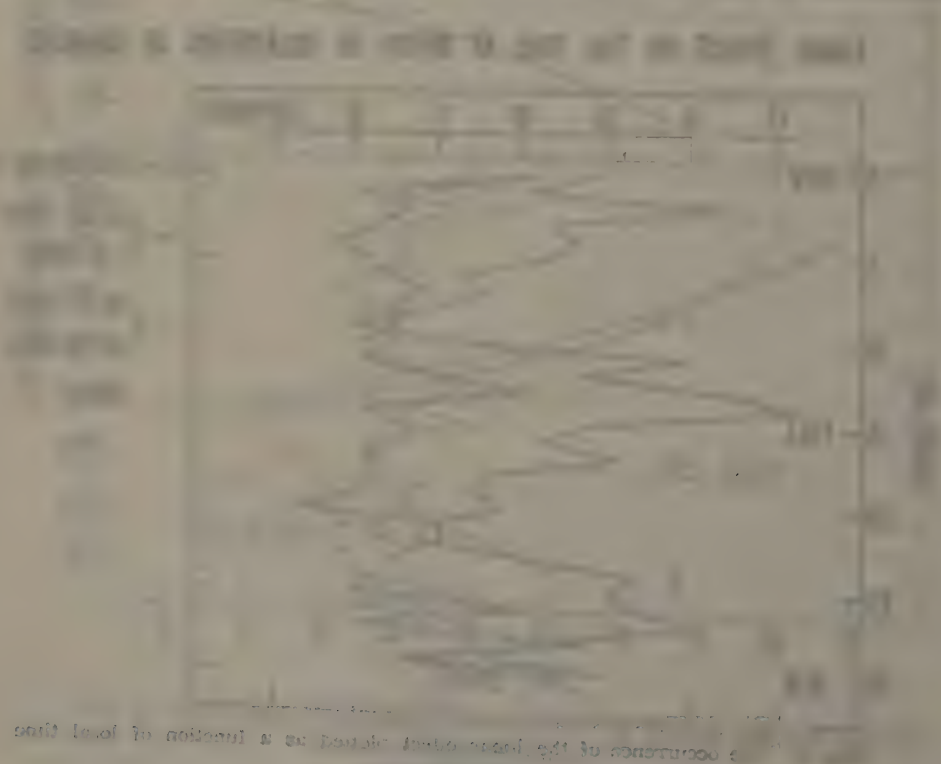


Fig. 4. The occurrence of the lunar effect plotted as a function of local time and lunar age.



the vicinity of the full and the new moons, equatorial E_s often disappears in the early afternoon. This relation is more conspicuous during the Dec.-solstice months (November to February) than during the June-solstice months (May to August), as will be seen in Fig. 4. On the other hand, equatorial E_s has a larger lunar tidal variation (about three times of that in $foF2$), as the author has already reported. [2] These results show that equatorial E_s is influenced not only by the electric current jet in the S_q layer but also by the lunar magnetic field.

The Seq. E_s at the equatorial region is a little different. The lifetime of this phenomenon is shorter than in moderate latitudes. Moreover, the Seq. E_s at Huancayo is often accompanied by the above-mentioned disappearance of equatorial E_s. Accordingly, the Seq. E_s at Huancayo seems to be influenced not only by the solar magnetic effect but also by the lunar magnetic effect. At other latitudes, the relation between the Seq. E_s and usual E_s is not definite.

In conclusion, the author wishes to express his thanks for support of the present study by Research Corporation and the Geophysics Research Directorate, Air Force Cambridge Research Center (under contract AF19(604)-969). He wishes also to express his sincere gratitude to Dr. L. V. Berkner, Dr. W. O. Roberts, Mr. A. H. Shapley, Mr. E.K. Smith, Mr. R.W. Knecht, Mr. S.C. Gladden, Miss M.A. Thomas and Mrs. L. Hayden for their kind help and advice, and to the Central Radio Propagation Laboratories, National Bureau of Standards for use of ionograms involved in this study and for extending to him the facilities of the Boulder Laboratories.

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(on leave from Kyoto University, Japan)

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[2] Matsushita, S., Rep. Ionosphere Res. Japan, 7, 45, (1953).

Meeting of the Society of Terrestrial Magnetism and Electricity:

The 18th General Meeting was held at the Tohoku University on October 28–30, 1955.

Number of the reports read at the Meeting:

Rock Magnetism and Electricity, 7; Palaeomagnetism, 2; Ionosphere and Radio Wave Propagation, 13; Earth Current and Geomagnetism, 12; Cosmic Rays, 9; Radio Meteorology and Atmospheric Electricity, 9; Simposium on the Origin of the Earth's Main Magnetic Field, 5.

Tanakadate Prize was awarded for the following excellent worker:

The 18th, Mr. H. Maeda;

Studies on Aeronomy on the Magnetic Equatorial Zone Based on Analysis of the Geomagnetic S_q-Variation.

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